

Blood Pressure Recording Practices Among Dental Hygiene Students

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Abstract

Purpose: The purpose of this study was to compare three different types of blood pressure (BP) recording devices (an automated arm cuff, an automated wrist cuff, and a manual cuff / stethoscope combination) for accuracy, patient comfort, and ease of operation.

Methods: Three types of sphygmomanometers were tested on 150 study participants (n=150) obtained from the patients presenting for dental hygiene services at an urban dental school in the Midwest. Descriptive statistics were calculated for all variables of interest by cuff type. Repeated measures ANOVA using the Greenhouse-Geisser adjustment were used to test for differences in means in BP and rating measure by cuff type. Post-hoc comparisons using Tukey's procedure were calculated to determine pair-wise differences. An association between the cuff type and convenience rating was evaluated using the Chi-square test, and between cuff type and convenience rating using the Fisher's exact test.

Results: There was a significant difference in systolic BP recording by cuff type ($p < 0.001$). The automatic wrist cuff recorded an average of 11.30mm and 8.76mm HG higher systolic BP than the standard cuff and the automatic arm cuff respectively ($p < 0.001$ for both). There was no significant difference in the systolic BP readings between the standard and automatic arm cuff ($p = 0.226$) nor was there a significant difference in diastolic BP by cuff type ($p = 0.137$).

Conclusion: Blood pressure cuff readings with traditional sphygmomanometer and stethoscope or an automated brachial cuff are comparable while wrist cuff BP readings deviated significantly. For consistency in blood pressure readings, the three different cuff types are not interchangeable.

Keywords: blood pressure determination, accuracy and precision, sphygmomanometers, validation, hypertension

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Introduction

Hypertension is characterized by excessive pressure on arterial walls as blood travels to and from the heart¹. It is a leading cause of both stroke and kidney disease and is often accompanied by obesity, diabetes, kidney disease or other problems affected by lifestyle and/or genetics. Increased systolic variability is associated with a higher risk for mortality and cardiovascular disease,² while greater variability in diastolic pressure increases the risk of cardiovascular events and adverse events in patients who have chronic kidney disease.³ A link between hypertension and periodontal disease has been suggested due to the observable alterations in localized inflammatory mechanisms such as tumor necrosis factor-alpha and C-reactive proteins⁴. Accurate blood pressure measurements are essential for recognizing a rising or elevated blood pressure, as well as monitoring a patient's compliance to prescribed treatment.⁵

The American Heart Association (AHA) in conjunction with the *Journal of Hypertension* previously defined hypertensive categories ranging from normal to hypertensive crisis.⁶ Based on those criteria, approximately one-third of all adults in the United States have hypertension⁷ and of those, only an estimated 54% are considered to be well controlled.^{8, 9} Recently, the American College of Cardiology (ACC) and the AHA released new guidelines for the detection, prevention, management and treatment of high blood pressure.¹⁰ The new guidelines further lower the definition of hypertension to allow for earlier intervention. Under the new guidelines, normal blood pressure is *less than* 120/80 mmHg while elevated blood pressure includes a systolic pressure between 120-129 with a diastolic still below 80. The increments continue to increase in 10mm Hg steps, ending in hypertensive crisis characterized by systolic pressure of 180 and/or diastolic pressure over 120 mmHg.¹⁰ According

to these updated guidelines, 46% of all adults in the U.S. are now considered to have hypertension.¹⁰ The guideline authors stress “the importance of using proper technique” and the use of validated devices to measure blood pressure.

Accurate assessment of a patient’s blood pressure is considered the standard of care for all initial and periodic diagnosis appointments in dentistry. Additionally, patients who have a history of hypertension should have their blood pressure evaluated before every appointment¹¹. In large part, this practice has resulted due to the frequency of visits in dentistry as compared to other healthcare settings. All health professionals are urged to aid in screening patients for hypertension.^{10, 12}

Blood pressure readings are obtained several ways. The standard sphygmomanometer cuff applies pressure around the upper arm and uses an analog dial to indicate the pressure (in mmHg) exerted by the cuff. It requires a stethoscope placed in the antecubital region to hear the heart beat as the sounds appear and disappear while the cuff is slowly deflated (Korotkoff sounds). This method is called both the auscultatory and the manual method. Common errors include not inflating the cuff adequately, deflating too rapidly, improper placement of the stethoscope, and an inability to hear the sounds clearly. This method has long been considered the “gold standard” of measuring blood pressure.¹³

Around 1981, automated sphygmomanometers for use on the upper arm were introduced into the market. These devices had a steady rate of cuff deflation and were not affected by a noisy environment as they did not require a stethoscope and were not based on auscultation. Automated devices employ an oscillometric measurement which utilizes the arterial cycles associated with the pumping of the heart.¹⁴ The cycles are then evaluated by an empirical algorithm to deliver a systolic and diastolic pressure reading¹⁵. More recent advances in some models include a memory bank for recent readings and an alert for an irregular heartbeat.

Wrist blood pressure cuffs were introduced around 1992. Wrist cuffs had all the advantages of the automated arm cuffs but also generally don’t require the patient to remove any clothing and are less affected by obesity.^{14, 16, 17} These devices also use oscillometric technology, but with the limitation of being further from the strength of the brachial pulse. All three types have been utilized in dental clinic settings.

Some studies have questioned the accuracy of automated sphygmomanometers.¹⁸⁻²¹ Wonka, and colleagues²¹ found wrist cuffs have issues with accuracy, Wan et al.²² conducted a systematic review of various devices, and found 81% of the 31 tested units passed the British Hypertension Society

protocol.²² However, validation procedures analyzed the data on a population basis and are not specific to individual factors such as how correctly the device protocol is followed.¹⁵ Additionally, several recordings were required to achieve acceptable accuracy.^{20, 22, 23} A systematic review conducted in 2011 found automated units varied widely when compared to the traditional mercury sphygmomanometer;¹⁸ two out of 16 studies were in direct contradiction with one another, and three out of 16 reporting an overestimated pressure with oscillometric cuffs. The cumulative result of the review was a cautionary statement regarding using oscillometric devices reserving their use for “special circumstances” such as those surrounding hypertension, preeclampsia, arrhythmia or post trauma.¹⁸

Inconsistencies in previous research motivated the authors to develop this cross-sectional study to directly compare representative samples of the three most common blood pressure measurement recording devices. The purpose of this study was to compare an automated arm cuff, an automated wrist cuff, and a traditional manual cuff /stethoscope combination for accuracy, patient comfort, and convenience/ease of operation in a dental setting among dental hygiene students.

Methods

This study was approved by the University of Missouri, Kansas City (UMKC) IRB (protocol #15-203). A sample of three types of sphygmomanometers were tested. The Accura Plus Sphygmomanometer/Stethoscope Kit, McC98002 (McCoy Health Science Supply, Maryland Heights, MO 63043) served as the traditional manual sphygmomanometer device. Automated arm units used were the ADC Advantage 6021N (American Diagnostic Corporation, Hauppauge, NY 11788), and the Veridian Model 01-5021 (Veridian Healthcare, Waukegan, IL 60085). The automated wrist cuff was the Veridian Model 01-516 (Veridian Healthcare, Waukegan, IL 60085). The Veridian Model 01-516 automated cuffs was the most frequently purchased model sold in the university book store to dental and dental hygiene students and was considered to best represent the current clinical environment. According to the literature obtained from the manufacturer, all sampled automated cuffs have been tested, validated, and approved by the Association for the Advancement of Medical Instrumentation, the British Hypertension Society, and the by the International Protocol for the Validation of Automated BP Measuring Devices.

Senior dental hygiene students who had successfully passed competency examinations in medical history review and vital data collection, approached, consented, and collected data from all participants. Participants were recruited from

the population of patients presenting for routine recall prophylaxis, scaling and root planing, or periodontal maintenance at the UMKC School of Dentistry. Collection of the data took place during the period of October 15, 2015 to July 21, 2016 (the close of the summer session). Informed consent was obtained verbally, after information documents were offered to patients. Patients verbally declining were excluded from the study, as were any patients who were not comfortable in the average sized upper arm and wrist cuffs by their own report. While larger cuffs exist for both the standard and automated arm cuffs, they were not utilized in this study, in order to keep the measurement process as straightforward as possible.

Standard, automatic arm and automatic wrist cuff measurements were taken on each participant. Prior to the beginning of the study, the cuffs to be used were made available in the dental hygiene treatment area for students to practice with. Additional instruction and coaching was not provided in an effort to simulate using new technology in practice, outside of the school setting. Before beginning the data collection, instructions were given verbally to students, including consulting the manufacturer's instructions for the automated cuffs. Data were collected on 150 participants (n=150) and recorded on a data collection form. During data collection, patients were seated upright in standard dental chairs, with blood pressure readings taken on their right arms. Care was taken to collect all three blood pressure recordings together before treatment, starting with the manual cuff stethoscope combination. There were fewer automated arm cuffs and wrist cuffs than there were participating student providers, therefore, devices were shared between patients and were

utilized as they were available by the student clinicians. Sharing the devices also allowed for a pause between readings for arterial circulation to return to normal. In the event that an error message was observed while using one of the automated cuffs, students attempted to complete the recording once more. If that was unsuccessful, they replaced the automated device's batteries. If no recording could be made using those two strategies, the data were omitted for that device.

The data collection form included systolic and diastolic measures for all three devices, as well as two Likert scales: clinicians evaluated convenience and patients evaluated comfort. The clinician evaluated the instruments for convenience (with a rating of one being "very inconvenient" and five being "very convenient") independently and silently, then recorded their patient's evaluation of the instrument for comfort (with a rating of one being "very uncomfortable" and five being "very comfortable"). The form concluded with a section for comments from both patients and clinicians. Data sheets were identified only by a sequential study number to monitor the number of participants. Data sheets were locked in a file cabinet in a locked office between clinic days.

Descriptive statistics (means and standard deviations) were calculated for all variables of interest by cuff type. Repeated measures ANOVA using the Greenhouse-Geisser adjustment and Eta-squared statistics were used to test for differences in means in blood pressure and rating measures by cuff type. Post-hoc comparisons using Tukey's procedure were calculated to determine pair-wise differences. The significance level was set to 0.05 and statistical analyses were performed using the software program Stata 14.1 (StataCorp LP, College Station, TX, USA). A sample size of 150 was considered by the authors to be adequate to obtain some measure of statistical accuracy.

Results

One hundred fifty participants were enrolled in the study. Participants had mean systolic and diastolic blood pressure of 128.99 ± 18.49 mmHG and 78.01 ± 11.33 mmHG respectively (Table I). There was a significant difference in systolic blood pressure by cuff type ($p < 0.001$). The automatic wrist cuff recorded an average 11.30 and 8.76 mmHG higher systolic blood pressure than the standard cuff and the automatic arm cuff respectively ($p < 0.001$ for both) (Table II). There was no significant difference in systolic blood pressure between the standard and automatic arm cuff ($p = 0.226$), nor was there a significant difference in diastolic blood pressure by cuff type overall ($p = 0.137$) (Table II). Cuff type explains 16% of the variability in systolic

Table I. Means and standard deviations of blood pressure variables by cuff type

	Cuff Type			Overall
	Standard	Automatic Arm	Automatic Wrist	
	N = 147	N = 149	N = 135	
	Mean (SD*)	Mean (SD*)	Mean (SD*)	Mean (SD*)
Systolic Blood Pressure	127.09 (17.03)	124.52 (10.86)	136.00 (23.99)	128.99 (18.49)
Diastolic Blood Pressure	78.20 (11.88)	76.94 (8.23)	78.99 (13.45)	78.01 (11.33)

*SD = Standard Deviation

Table II. Associations between blood pressure variables and cuff type using repeated measures ANOVA with Tukey post-hoc comparisons and Eta-squared statistics.

	Mean Difference	95% CI*	Eta- squared (η^2)	95% CI*	p-value
Systolic Blood Pressure			0.16	(0.09, 0.24)	< 0.001**
Standard vs Automatic Arm	-2.53	(-6.15, 1.08)			0.226
Automatic Wrist vs Automatic Arm	8.76	(5.01, 12.52)			< 0.001
Automatic Wrist vs Standard	11.30	(7.56, 15.03)			< 0.001
Diastolic Blood Pressure			0.01	(0, 0.05)	0.137**
Standard vs Automatic Arm	-1.23	(-3.57, 1.11)			0.433
Automatic Wrist vs Automatic Arm	0.83	(-1.60, 3.26)			0.702
Automatic Wrist vs Standard	2.05	(-0.36, 4.47)			0.113
Comfort Rating			0.12	(0.06, 0.19)	< 0.001**
Standard vs Automatic Arm	0.67	(0.39, 0.94)			< 0.001
Automatic Wrist vs Automatic Arm	0.60	(0.32, 0.88)			< 0.001
Automatic Wrist vs Standard	-0.06	(-0.34, 0.21)			0.845
Convenience Rating			0.04	(0.01, 0.09)	0.004**
Standard vs Automatic Arm	-0.35	(-0.62, -0.09)			0.005
Automatic Wrist vs Automatic Arm	-0.04	(-0.31, 0.23)			0.945
Automatic Wrist vs Standard	0.31	(0.05, 0.58)			0.016

*CI = Confidence Interval

**Greenhouse-Geisser calculation used for ANOVA p-value

blood pressure and 1% of the variability in diastolic blood pressure (Eta-squared=0.16, 0.01 respectively).

There was a significant difference in patient comfort rating by cuff type ($p < 0.001$). The comfort rating averaged 0.67 and 0.60 higher (more comfortable) in the standard and automatic wrist cuff (respectively) on the 5-point Likert scale than in the automatic arm cuff ($p < 0.001$ for both). There were no significant differences in comfort rating between the automatic wrist cuff and the standard cuff ($p = 0.845$) (Table II). Cuff type explains 12% of the variability in comfort rating and 4% of the variability in convenience rating (Eta-squared= 0.12, 0.04 respectively).

There was also a significant difference in clinician convenience rating by cuff type ($p = 0.004$). Dental hygiene students rated the automatic arm and wrist cuff higher (more convenient) than the standard cuff by an average of 0.35 and

0.31 respectively ($p = 0.005$ and 0.016 respectively) on the 5-point Likert convenience scale. There was not a significant difference in convenience rating between automatic wrist cuff and the automatic arm cuff ($p = 0.945$)

Discussion

Clinicians have many options among traditional sphygmomanometers, automated arm cuffs, and automated wrist cuffs when selecting an optimal blood pressure cuff. This study sought to compare three types in an academic dental hygiene setting and help illustrate the best options for use by both students and clinicians. Reviewing the findings of the three types of blood pressure cuffs compared in this study, readings from the automated arm cuff and standard sphygmomanometer were the most consistent with each other, while readings from the automated wrist cuff were significantly less consistent.

Previous studies have demonstrated limitations regarding the calibration, ease of use, and consistency of automated wrist cuffs. Measurements from the more distal locations (further from the brachial arteries) are associated with an increase in systolic and a decrease in diastolic pressure.¹⁵ Eight percent of the dental hygiene students in this study made comments about a “distrust” of the wrist cuff’s readings. They questioned the methods for correct wrist cuff reading and usage when they differed from those used in the other two devices, and mentioned patient discomfort with the wrist cuff. It is possible that results were impacted by improper use, fit, or application of the wrist cuff, despite the verbal instructions the students received to read the manufacturer’s instructions. Reading and applying the manufacturers’ instructions could limit these errors. New technologies are often adopted in practice, and without personal diligence in following their instructions for use, a lack of accuracy could occur.

In this study, some patients and clinicians reported being skeptical of the automated arm cuff. Comments on data sheets indicated a general “dislike” of the automated arm cuff by 9% of the patients, citing the tightness of the cuff, with one patient reporting discoloration of his/her hand during measurement. Similar to a traditional sphygmomanometer, brachial arm circumference can differ significantly from one patient to the next.²⁴ Outfitting an automated arm cuff with the appropriate attachment for larger brachial arm circumference could improve patient and clinician perception of the devices. Further, the automated arm cuff is not governed by the presence or absence of the Korotkoff sounds, meaning the maximum pressure may be more standardized than customized, leading to more pressure than the patient is accustomed to with an automated arm cuff from the standard cuff.

Future studies should collect the opinion of the clinician separately and discretely from the opinion of the patients and vice versa. The automatic component on both the automated devices (wrist and arm) is both a convenience and a possible detriment. On several occasions, data were missing due to the cuff’s inability to compute, usually because of an internal error or an expired battery. When an error message was observed, the students made another attempt and if that was not successful, the batteries were changed. This could be considered a lack of dependability of the device, or an inconvenience which could add time to an appointment or potentially result in a lack of willingness to take blood pressure with the device. Automated arm cuff data was missing on three patients, while 15 readings were missing for the automated wrist cuff. This suggests the wrist cuff was harder to use than the standard or automatic arm cuffs despite some favorable clinician comments on efficiency, fit or ease of use.

A limitation in this study was that blood pressure measurements were taken by multiple students (n = 59) who had different levels of skill and experience with blood pressure measurement. This could have resulted in missing data due to operator error and lack of familiarity with the equipment. It could have also resulted in the variability across the three cuff types that was higher in some of the students. Future studies should focus on calibration of the examiners which should reduce errors and address examiner variability.

Another study limitation was a lack of protocol for the length of time that must elapse between blood pressure measurements. A delay occurred between readings however a timer was not used to standardize the pause. According to the AHA,^{26,27} five minutes of quiet rest should elapse between readings to prevent a falsely high blood pressure reading. Future studies should standardize this pause in the protocol. Lastly, the order of the cuff selection was not randomized. Cuffs were used depending on their availability in the dental hygiene clinic, although in most cases the manual cuff was used first. Cuff selection order could have led to biases in determining the differences between the cuff types. Future studies should randomize the cuff order for each subject.

Despite the limitations, the results of this study help inform the health care provider. The results of this study confirm those of others^{21,22} linking the use of automated wrist cuffs with decreased accuracy. When technology advances, it is likely that techniques need to change in order to ensure best practice. The importance of provider’s reading and following the manufacturer instructions is emphasized. Providers should continue to rely on the skills they have developed in evidence-based decision making, rather than limiting their selection of blood pressure devices based on convenience and proximity.

Conclusion

Blood pressure readings obtained with a traditional sphygmomanometer/stethoscope combination were comparable to those obtained with an automated brachial arm cuff, while blood pressure readings taken from a wrist cuff deviated significantly. Although convenience of a wrist cuff device is an important factor, accuracy should not be compromised. Some deviations in the data captured between cuff types may be explained by the student operators failing to follow the manufacturers’ instructions, highlighting the need for adherence to manufacturer instructions for any new clinical equipment. When electing to adopt a new device for blood pressure measurement, clinicians and educators should research the device’s validity as published in the literature, and ensure users are guided in proper protocol(s) for use. In

the measurement of consistent and calibrated blood pressure, measurements are not interchangeable with the three different cuff types.

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